

# BIRD COMMUNITY COMPOSITION IN RELATION TO HABITAT AND SEASON IN BETATAKIN CANYON, NAVAJO NATIONAL MONUMENT, ARIZONA<sup>1</sup>

Jack D. Brotherson<sup>2</sup>, Lee A. Szyska<sup>2</sup>, and William E. Evenson<sup>3</sup>

**ABSTRACT.**— Bird species density, diversity, and species richness in relation to habitat and seasonal variations were studied in the Betatakin Canyon area of Navajo National Monument, Arizona. The two most prominent habitat types are a riparian forest deep in the canyon bottom and a mature pinyon-juniper woodland on the mesas and slopes above the canyon. One hundred thirty-five species of birds were encountered during the study and recorded by season and habitat. The avifauna assemblages demonstrate definite habitat selection into groups associated with the riparian and pinyon-juniper woodland communities. Diversity, density, and species richness were greatest in the riparian habitat during the spring and summer months. The differences in bird community composition were greater between seasons than between habitats. Pinyon pine and Gambel oak were highly selected as perch sites in the pinyon-juniper and riparian areas, respectively.

As part of an ongoing ecological survey of Navajo National Monument, we studied the bird communities and report here their ecological relationships with respect to vegetation and season.

The effects of habitat diversity and seasonal change on bird species diversity have been extensively documented in ecological literature (MacArthur and MacArthur 1961, Karr and Roth 1971, Willson 1974, Karr 1976, Roth 1977, Balda and Masters 1980). Two of the most commonly investigated components of habitat diversity are foliage height and plant species composition (MacArthur and MacArthur 1961). Willson (1974) demonstrated that as forest canopy becomes increasingly stratified, additional foraging guilds (bird groups of similar foraging habitat and behavior) are able to invade, thus increasing species diversity. The inter-relationship between species diversity, foliage height, and vegetational complexity has been explored by a number of researchers (Johnston and Odum 1956, Johnsgard and Rickard 1957, Karr 1968, Cody 1974, Yeaton 1974, Whitmore 1975 and 1977, Johnson 1975).

In more complex habitats, however, foliage height diversity alone is not a reliable predictor of species diversity. MacArthur and MacArthur (1961) suggested that birds living

in desert scrub might require more than foliage height differences to partition their environment. This was subsequently confirmed by Tomoff (1974), who found that plant species composition was the best determinant of bird species diversity in desert scrublands. He suggested that the extreme diversity in growth forms of desert plants would provide greater habitat variability than would differences in mature plant height.

## STUDY SITE

Navajo National Monument is in northeastern Arizona about 16 km northwest of Black Mesa and Arizona Highway 160. The principle sites of the monument are three large Anasazi Indian cliff dwellings located in three separate canyons. Betatakin Canyon belongs to the Tsegi Canyon complex, which has been described by several authors (Gregory 1916 and 1917, Hack 1942 and 1945, Harshbarger et al. 1957, Cooley 1958, 1962, Woodbury 1963).

The major geological formation within Betatakin Canyon is the Navajo Sandstone, which forms sheer cliffs towering more than 200 m above the canyon floor. The floor itself, at an altitude of about 2100 m, consists of deep alluvial deposits of sandy Quaternary fill, overlain by talus at the base of the cliffs.

<sup>1</sup>Completed as part of Contract PX7029-8-0570 from the Southwest Region of the National Park Service.

<sup>2</sup>Department of Botany and Range Science, Brigham Young University, Provo, Utah 84602.

<sup>3</sup>Department of Physics and Astronomy, Brigham Young University, Provo, Utah 84602.

The Kayenta Sandstone formation outcrops beneath the Navajo and is occasionally seen in the lower reaches of the canyon.

The annual temperature recorded at Park headquarters within the Monument ranges from -23 to 38 C, with a mean of 10 C. The number of frost-free days during the year varies from 107 to 213, with an average of 155 days. Total annual precipitation in Betatakin has historically ranged from 17 cm to 48 cm, with a yearly mean of 29 cm. There is a single wet season, lasting from late summer to early fall. Rainfall within the canyon is variable and spotty, with localized cloudbursts rather than large regional storms.

A mature pinyon-juniper community occurs on the mesa and slopes above the canyon and extends onto the exposed slickrock and walls that slope down to the canyon floor. Although pinyon pine (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*) are consistently the dominant overstory species, there are 3 distinctive understory communities (Brotherson et al. 1980) dominated by big sagebrush (*Artemisia tridentata*), littleleaf mountain mahogany (*Cercocarpus intricatus*), and a mixed shrub zone consisting of cliffrose (*Cowania mexicana*), antelope bitterbrush (*Purshia tridentata*), cliff fendlerbush (*Fendlera rupicola*), and roundleaf buffaloberry (*Shepherdia rotundifolia*).

A riparian forest and associated trees grow on the canyon floor and along the talus banks above the intermittently flowing stream. Many of the plant species found here are usually associated with high mountain habitats. The dominant species include quaking aspen (*Populus tremuloides*), box elder (*Acer negundo*), water birch (*Betula occidentalis*), redbud dogwood (*Cornus stolonifera*), Gambel oak (*Quercus gambelii*) and Douglas fir (*Pseudotsuga menziesii*).

#### METHODS

Birds were censused during all four seasons of the year by the transect method (Emlen 1971 and 1977) on 7-10 May, 8-10 July, 6-7 November 1978 and 19-21 February 1979. Three transects, each one-half mile in length, were established as follows: one in the canyon bottom, one in the pinyon-juniper-mixed shrub community type, and one in the

pinyon-juniper sage community type. Censusing was done in early morning and evening on three consecutive days each season. During a separate spring and summer census from May through August of 1977, five Emlen transects were run twice a month, and the perching site of each bird seen was also recorded. Birds observed flying through the area were not included in the analyses, although such sightings are included in the species list for the monument.

Types of habitat were distinguished on the basis of vegetational differences (Brotherson et al. 1980). Standard diversity indices ( $H'$ ,  $J'$ ) were calculated for the bird assemblages seasonally and within the different habitats (Pielou 1975). The diversity of a community depends on two variables: (1) number of species present and (2) evenness with which the individuals of the species are scattered through the community (Kricher 1972). To describe a community's diversity only in terms of its diversity index ( $H'$ ) is to confound these two factors. A community with a few, evenly represented species can have the same diversity index as one with many, unevenly represented species. Therefore, we also calculated the equitability index, ( $J'$ ) that is designed to measure this evenness component (Lloyd and Ghelardi 1964). (See May 1975 for a review of diversity indices and their applicability.)

Niche width and niche overlap values (Colwell and Futuyma 1971) were also calculated. Niche width is a measure of the breadth of use of the available resources (in this study, habitat types and seasons). Niche overlap measures the amount of mutual utilization of resources by two species.

Birds were clustered, using unweighted pair group averages, on niche overlap (Sneath and Sokal 1963), using as resource bases habitat type, individual perch site, and seasonal occurrence. Additional cluster analyses were run to check the effects of seasonality and habitat, using Ruzicka's (1958) similarity index, without respect to niche overlap.

#### RESULTS

One hundred thirty-five species of birds are known from Navajo National Monument

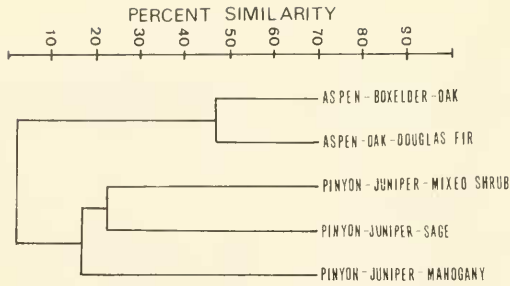


Fig. 1. Dendrogram of the cluster analysis of bird habitat information taken in the spring and summer of 1977 using Emlen transects.

(Appendix). Sixty-six species were noted in Betatakin Canyon during the 1978–1979 census, and 43 during the spring 1977 census. Of these 43, 10 were eliminated from our analyses because they were only sighted once.

The avifauna assemblages demonstrate definite habitat selection. A clustering of the data from the spring and summer census of 1977 (Fig. 1) shows a clear separation of the bird fauna associated with the riparian and pinyon-juniper communities (2 percent similarity). Subzones of the riparian communities are distinguished as streambank habitats (aspen, box elder, and some Gambel oak) and talus slope habitats above the stream (aspen, Gambel oak, and Douglas fir). The subzones of the pinyon-juniper communities are distinguished by their principle understory species (sagebrush, mountain mahogany, and mixed shrubs). Later analyses lumped the subzones of the riparian community into one. Those of the pinyon-juniper community were lumped into two by combining the P-J mahogany subzone with the P-J mixed shrub subzone because these two P-J subzones are floristically almost indistinguishable (Brotherson et al. 1980).

The riparian and pinyon-juniper communities support highly distinct avifauna. The riparian habitat supports nearly a third more species than the pinyon-juniper habitat (Table 1). The total density of individuals in the riparian communities is about 60 percent greater than the mixed shrub zone. The number of species seems to be the major factor determining diversity in the avian community rather than the relative abundances of the species present.

Avian niche widths are similar during the spring and summer. Average niche overlap

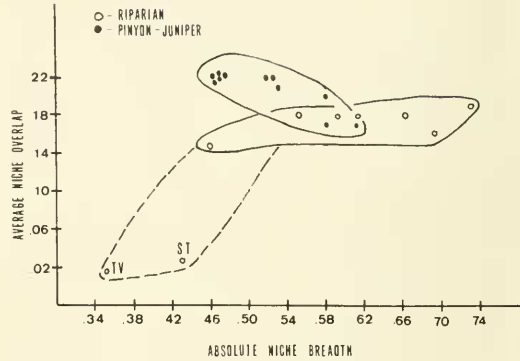


Fig. 2. Graph of average niche overlap values against absolute niche width values from data taken in summer. Depicts only riparian species and pinyon-juniper species restricted to those zones.

(mean of all niche overlaps between a given species and all other species) against absolute niche width is shown in Figure 2. Only those birds found exclusively in either the pinyon-juniper or riparian habitats were included. Exclusion of the two outlying points (Turkey vulture and Swainson’s thrush, which were observed only in the Douglas fir and on the ground), suggest that habitat use, as deduced from the niche metrics, is similar in the two communities (Fig. 2).

Habitat use patterns change through the year. The pinyon-juniper-sage and mixed-shrub zones remain similar, as expected, but riparian habitat use becomes much broader (Fig. 3). Early spring migrants arriving before the riparian forest has leafed out face limited resources and are therefore forced to forage widely. The deciduous nature of the forest also precludes specialization during the winter months when food resources become scarce.

TABLE 1. Major habitat types along with their total number of bird species, total densities (D) and diversities (H', J').

| Community type             | No. of avian species | D    | H'    | J'   |
|----------------------------|----------------------|------|-------|------|
| Riparian                   | 46                   | 17.4 | 1.455 | .380 |
| Pinyon-Juniper-Sage        | 34                   | 15.4 | 1.301 | .389 |
| Pinyon-Juniper-Mixed shrub | 36                   | 10.8 | 1.307 | .305 |

D = Total densities of all individuals present per ha  
 H' = Shannon-Weaver Diversity index =  $\sum p_i \log p_i$  where  $p_i$  equals the proportion of a species in the whole community.  
 J' = Equitability index =  $H' / \log S$  where S = total number of species present in habitat.



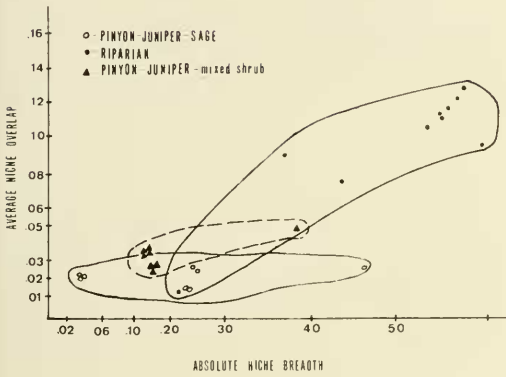


Fig. 3. Graph of average niche overlap values against absolute niche width values from data taken throughout the year. Depicts values for birds restricted to any one of the three habitat types sampled: riparian, pinyon-juniper, and pinyon-juniper-mixed shrub.

Perch Site Selection

The spring-summer census of 1977, which recorded specific perch sites, permits examination of tree use within and between habitats. We identified the nine most frequently chosen perches (those plant species with less than three sightings were excluded from analysis) and calculated diversity indices (Table 2). Excluding the ground category, which is common to both communities, riparian habitat has 26 percent more bird species than pinyon-juniper, but the largest numbers of birds are found in pinyon pine and oak. The use of pinyon pine and oak is not simply a function of availability, because cover of mature pinyon pines and junipers is approximately equal in the P-J community, and cover of Gambel oak and aspen is approximately

TABLE 2. Perching sites of birds from the spring-summer census of 1977. N = total number of individuals, H' = Shannon-Weaver diversity index, J' = equitability (see Table 1).

| Perching sites | No. of species | N   | H'    | J'   |
|----------------|----------------|-----|-------|------|
| Aspen°         | 11             | 42  | .910  | .379 |
| Box elder°     | 9              | 43  | .855  | .389 |
| Gambel oak°    | 19             | 137 | 1.037 | .352 |
| Douglas fir°   | 10             | 49  | .555  | .241 |
| Dogwood°       | 4              | 6   | .578  | .417 |
| Pinyon         | 23             | 149 | 1.025 | .327 |
| Juniper        | 12             | 24  | .994  | .400 |
| Mahogany       | 7              | 58  | .366  | .188 |
| Ground         | 5              | 28  | .513  | .319 |

°R = Riparian community  
 °P-J = Pinyon-juniper community

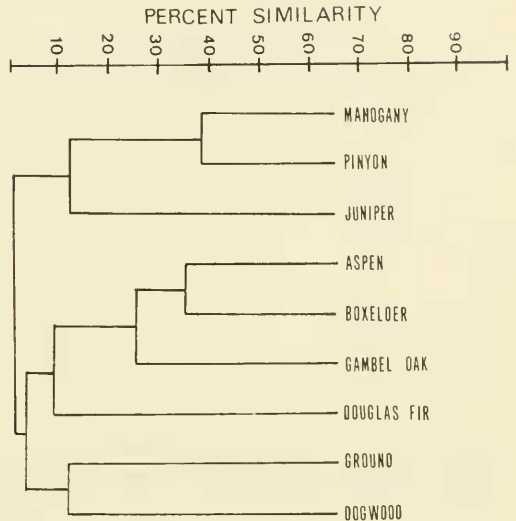


Fig. 4. Dendrogram of the cluster analysis of perch site choice of bird species (summer 1977 data only).

equal in the riparian community. Furthermore, box elder also makes a substantial contribution to cover in the riparian community. The disproportionate use of pinyon and oak is reflected in the high H' values and the lower J' values, suggesting that these tree species are used preferentially by many species throughout the spring and summer. This unequal use of pinyon pine and oak is possibly due to greater availability of insects associated with these trees (Balda 1969) than with neighboring juniper or aspen (S. L. Wood, pers. comm.). In addition, greater foliage density in oak than in aspen may attract some birds.

Cluster analysis applied to the perching data taken in the 1977 census (Fig. 4) exhibits general patterns similar to those shown in Figure 1 and confirms the distinction between bird communities in the riparian and pinyon-juniper habitats. It also permits separation of the subzones within these communities by their bird species components. Figure 5 shows a cluster by niche overlap of 33 bird species associated with the recorded perch sites. The cluster identified 9 major groups (for species identification within each group, see Table 3).

Seasonality

Numbers of both species and individuals increase during the spring and summer, with

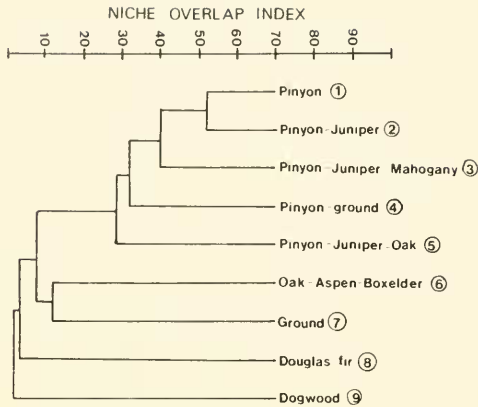


Fig. 5. Dendrogram of the cluster analysis of 33 bird species by niche overlap from perch site data. For identification of bird species found in each group see Table 3.

correspondingly high diversity values (Table 4). The avifaunal similarities are greater in all habitat types in spring-summer versus the fall-winter component in the same habitat (13 percent similarity, Fig. 6). Nevertheless, the riparian fauna is clearly distinct from the pinyon-juniper-sage and pinyon-juniper-mixed shrub fauna in both the spring-summer and fall-winter seasons (Fig. 7). The two pinyon-juniper subzones are distinguished only during the fall and winter months, become less so in spring, and show high similarity (56 percent) during the summer.

A clustering of all 66 bird species according to season identifies six major groups corresponding to summer resident, winter resident, and permanent resident categories, as well as migrants in the appropriate season (Fig. 8).

Habitat Preference and Niche Overlap

Niche overlaps of all 66 species are represented by a cluster diagram (Fig. 9). The birds were clustered according to both season and habitat. The clustering identifies 13 major groups (For species identifications within each group, see Table 6). Birds restricted to the pinyon-juniper-sage and pinyon-juniper-mixed shrub habitats (habitats with the least apparent floristic diversity), and those found in the canyon during the harsh winter months show the narrowest niches and the least overlap with other species. Those found in the riparian forest or during the spring and summer months have broader niches and show considerably greater niche overlaps (Figs. 2, 3, and 10). Our data do not permit us to differentiate between birds that are better adapted to harsher, resource-poor habitats and those that are competitively excluded from other areas and subsisting on the extreme edge of their habitat tolerance. In other words, we cannot clearly separate local seasonal exclusions from habitat selectivity (Rosenzweig 1975).

TABLE 3. Bird species grouped by cluster analysis of niche overlaps (date from perch site information). Table corresponds to Figure 4.

| Group | Species                                                                               | Group | Species                                                                                                                                                                                                                                             |
|-------|---------------------------------------------------------------------------------------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1     | Mourning Dove<br>Violet-green Swallow<br>Brown-headed Cowbird<br>Bluebird<br>Bushtit  | 6     | Virginia's Warbler<br>Sharp-shinned Hawk<br>Audubon's Warbler<br>Black-headed Grosbeak<br>Hairy Woodpecker<br>Dusky Flycatcher<br>Warbling Vireo<br>Downy Woodpecker<br>Ruby-crowned Kinglet<br>White-breasted Nuthatch<br>Hermit Thrush<br>Flicker |
| 2     | Black-throated Gray Warbler<br>Rock Wren<br>Gray Flycatcher<br>Plain Titmouse         | 7     | Rufous-sided Towhee<br>Swainson's Thrush                                                                                                                                                                                                            |
| 3     | Chipping Sparrow<br>Common Bushtit                                                    | 8     | Black-capped Chickadee<br>Turkey Vulture                                                                                                                                                                                                            |
| 4     | Gray-headed Junco                                                                     | 9     | Wilson's Warbler                                                                                                                                                                                                                                    |
| 5     | Black-chinned Hummingbird<br>Scrub Jay<br>Blue-gray Gnatcatcher<br>Mountain Chickadee |       |                                                                                                                                                                                                                                                     |

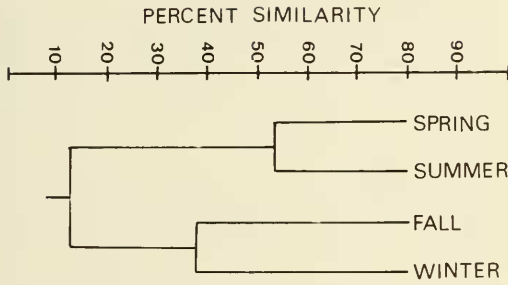


Fig. 6. Dendrogram of the cluster analysis of data on bird communities by season.

DISCUSSION

Bird species diversity in Betatakin Canyon follows plant species diversity, with different avifaunal assemblages occurring in the deciduous riparian and evergreen scrub communities. The birds of Betatakin are not randomly distributed through the canyon, but are specific to habitat and season. Habitat selectivity has long been known to occur between successional stages of forests, with entire suits of fauna replacing one another as a forest succeeds toward the climax stage (Johnston and Odum 1956, Johnsgard and Rickard 1957).

Tomoff (1974) demonstrated that plant species diversity and lifeform were the best predictors of bird species diversity in desert scrubland. Our data support this hypothesis; plant species diversities were 4.6 in the riparian community and 2.3–2.6 in the two P-J zones. The data also suggest that the full range of plant species diversity in Betatakin is required to maintain the high diversity of bird species found there. This implies that species diversity may be tied to availability of niches (Rosenzweig 1975).

There are some theoretical anomalies worth considering because they point out

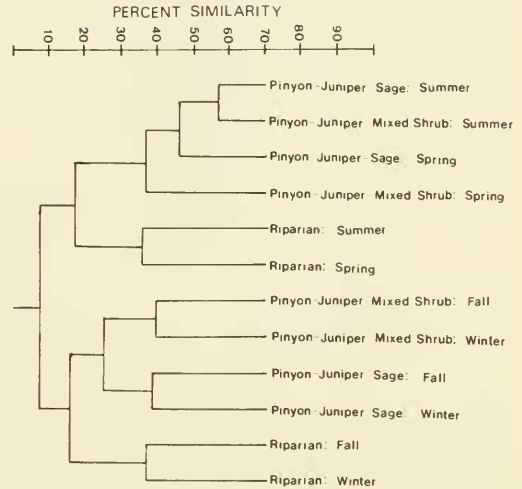


Fig. 7. Dendrogram of the cluster analysis of data on bird communities by habitat and by season.

factors peculiar to the canyon. Assuming that resource availability peaks in the spring and summer, and if abundant resources permit extensive resource partitioning, then both niche width and niche overlap should be smallest in the spring and summer (Fig. 10). The reverse is occurring, however, and several factors may help to explain this. First, during the late fall and winter, the available food resources become localized in the dried fruits and seeds of the riparian forest and in the limited remaining evergreen community. Regardless of abundance, this narrow resource spectrum automatically generates mathematically small niche widths, although one might expect niche overlap to be greater than observed. The small niche overlap values obtained may be a result of the species pool dropping from 45 in the summer to 12 in the winter, a loss of almost 75 percent. Resource partitioning may have occurred

TABLE 4. Summary of population data collected on census in the Betatakin Canyon area of Navajo National Monument.

| Habitat type               | Number of species |    |   |   | Mean density* |     |     |     | Shannon-Weaver (H') |      |      |      |
|----------------------------|-------------------|----|---|---|---------------|-----|-----|-----|---------------------|------|------|------|
|                            | Sp                | S  | F | W | Sp            | S   | F   | W   | Sp                  | S    | F    | W    |
| Riparian                   | 34                | 26 | 7 | 5 | 5.7           | 7.0 | 1.9 | 1.6 | 1.71                | 1.19 | 0.83 | 0.34 |
| Pinyon-Juniper mixed shrub | 24                | 27 | 5 | 7 | 3.8           | 4.9 | 1.5 | 0.7 | 0.87                | 1.38 | 0.56 | 0.57 |
| Pinyon-Juniper-Sage        | 22                | 24 | 9 | 9 | 5.4           | 3.6 | 3.7 | 2.7 | 1.14                | 1.23 | 0.68 | 0.82 |

Sp = Spring. Census period: 7–10 May  
 S = Summer. Census period: 8–11 July  
 F = Fall. Census period: 6–7 November  
 W = Winter. Census period: 19–21 February  
 \*Individual birds per ha.

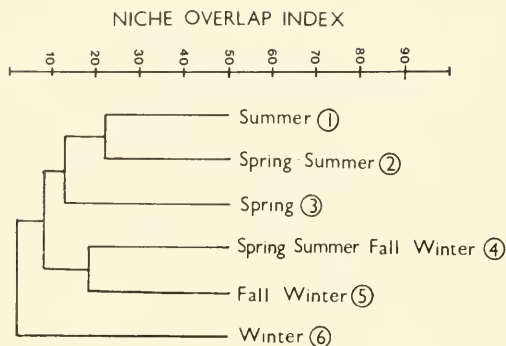


Fig. 8. Dendrogram of the cluster analysis of 66 bird species by niche overlap from seasonal data. For identification of bird species found in each group see Table 5.

despite the low number of species present and the narrow resource spectrum.

Second, although the bird species pool rapidly increases in the early spring (up to 48),

not all the vegetation has emerged by May, nor are insects yet very abundant. Thus, the strain upon available food resources should encourage broad niche widths and considerable niche overlap at that time, which is what our data show. Moreover, as the summer fruits and leaves appear, resources increase; but so do the numbers of newly fledged young, and niche widths drop only slightly. By the time of our fall census in November, the species pool is drastically reduced, and seeds are abundant; thus species can be much more selective and narrow their niche width.

ACKNOWLEDGMENTS

We thank Hal L. Black, Thomas L. Thunrow, and John A. Fairchild for their help in

TABLE 5. Bird species grouped by cluster analysis of niche overlaps (Data from seasonal information). Table corresponds to Figure 8.

| Group                    | Species                     | Group      | Species                  |                     |                        |
|--------------------------|-----------------------------|------------|--------------------------|---------------------|------------------------|
| 1                        | Audubon's Warbler           | 3          | Band-tailed Pigeon       |                     |                        |
|                          | Black-capped Chickadee      |            | Brown-headed Cowbird     |                     |                        |
|                          | Black-headed Grosbeak       |            | Gray-headed Junco        |                     |                        |
|                          | Western Bluebird            |            | Common Grosbeak          |                     |                        |
|                          | Black-chinned Hummingbird   |            | Mountain Bluebird        |                     |                        |
|                          | Cassin's Kingbird           |            | Vesper Sparrow           |                     |                        |
|                          | Gray Flycatcher             |            | Yellow Warbler           |                     |                        |
|                          | Lesser Goldfinch            |            | Yellow-rumped Warbler    |                     |                        |
|                          | Red Crossbill               |            | Orange-crowned Warbler   |                     |                        |
|                          | Virginia's Warbler          |            | Red-breasted Nuthatch    |                     |                        |
|                          | Western Tanager             |            | Ruby-crowned Kinglet     |                     |                        |
| 2                        | Rufous-sided Towhee         | 4          | Swainson's Thrush        |                     |                        |
|                          | Say's Phoebe                |            | Wilson's Warbler         |                     |                        |
|                          | Common Bushtit              |            | Yellow-bellied Sapsucker |                     |                        |
|                          | Cooper's Hawk               |            | 5                        | Black-billed Magpie |                        |
|                          | Violet-green Swallow        |            |                          | Sharp-shinned Hawk  |                        |
|                          | Hermit Thrust               |            |                          | Dark-eyed Junco     |                        |
|                          | Blue-gray Gnatcatcher       |            |                          | Stellar's Jay       |                        |
|                          | Solitary Vireo              |            |                          | 6                   | Cassin's Finch         |
|                          | Green-tailed Towhee         |            |                          |                     | Golden-crowned Kinglet |
|                          | White-throated Swift        |            |                          |                     | Brown Creeper          |
|                          | Bewick's Wren               | Pinyon Jay |                          |                     |                        |
|                          | Western Flycatcher          |            |                          |                     |                        |
|                          | MacGillivray's Warbler      |            |                          |                     |                        |
|                          | Warbling Vireo              |            |                          |                     |                        |
|                          | Downy Woodpecker            |            |                          |                     |                        |
|                          | Traill's Flycatcher         |            |                          |                     |                        |
|                          | Black-throated Gray Warbler |            |                          |                     |                        |
|                          | Mourning Dove               |            |                          |                     |                        |
|                          | House Wren                  |            |                          |                     |                        |
|                          | Chipping Sparrow            |            |                          |                     |                        |
| Ash-throated Flycatcher  |                             |            |                          |                     |                        |
| Broad-tailed Hummingbird |                             |            |                          |                     |                        |
| Canyon Wren              |                             |            |                          |                     |                        |
| Rock Wren                |                             |            |                          |                     |                        |

data collection and Clayton M. White and Jerran T. Flinders for their constructive review of the manuscript.

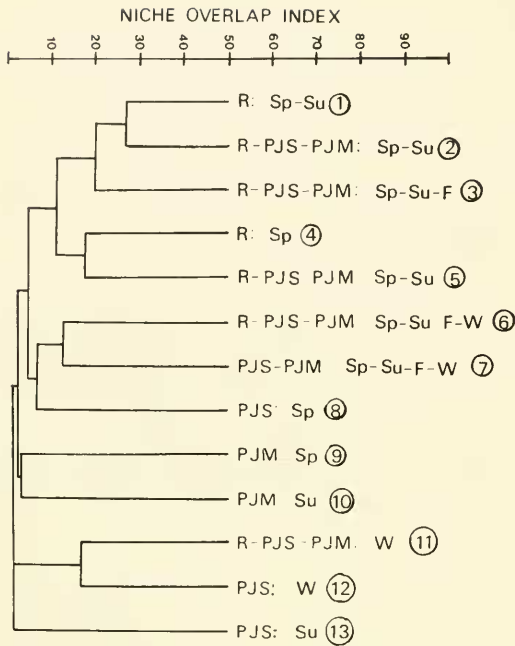
## LITERATURE CITED

- BALDA, R. P. 1969. Foliage use by birds of the oak-juniper woodland and ponderosa pine forest in south-eastern Arizona. *Condor* 71:399-412.
- BALDA, R. P., AND N. MASTERS. 1980. Avian communities in the pinyon-juniper woodland: A descriptive analysis. Pages 146-167 in *Workshop proceedings, management of western forests and grasslands for nongame birds*. USDA Forest Service General Technical Report INT-86.
- BROTHERSON, J. D., S. R. RUSHFORTH, W. E. EVENSON, L. A. SZYSKA, J. FAIRCHILD, J. R. JOHANSEN, AND C. MORDEN. 1980. Ecological studies at Navajo National Monument. Part II. Report. National Park Service, Southwest Region and Navajo National Monument. 227 pp.
- CODY, M. L. 1974. Competition and the structure of bird communities. *Monographs in population biology*. Princeton University Press, Princeton, New Jersey. 318 pp.
- COLWELL, R. K., AND D. J. FUTUYMA. 1971. On the measurement of niche breadth and overlap. *Ecology* 52:567-576.
- COOLEY, M. E. 1958. Physiography of the Glen-San Juan Canyon area. Part I. *Plateau* 31:21-33.
- . 1962. Late Pleistocene and recent erosion and alluviation in parts of the Colorado River system, Arizona and Utah. Pages 48-50 in *Geological survey research 1962: short papers in geology, hydrology, and topography*, articles 1-59. United States Geological Survey Professional Paper 450-B. Washington, D.C.
- EMLEN, J. T. 1971. Population densities of birds derived from transect counts. *Auk* 88:323-342.

TABLE 6. Bird species grouped by cluster analysis of niche overlaps (data from season and habitat information). Table corresponds to Figure 9.

| Group | Species                                                                                                                                                                    | Group | Species                                                                                                                                      |
|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|----------------------------------------------------------------------------------------------------------------------------------------------|
| 1     | Black-headed Grosbeak<br>Western Tanager<br>Cooper's Hawk<br>MacGillivray's Warbler<br>Warbling Vireo<br>Western Flycatcher<br>Virginia's Warbler<br>Traill's Flycatcher   | 6     | Hairy Woodpecker<br>Plain Titmouse<br>House Finch<br>Raven<br>White-breasted Nuthatch<br>Mountain Chickadee<br>Dark-eyed Junco<br>Pinyon Jay |
| 2     | Brown-headed Cowbird<br>Yellow-rumped Warbler<br>House Wren<br>Rock Wren<br>Ash-throated Flycatcher<br>Black-throated Gray Warbler<br>Blue-gray Gnatcatcher<br>Canyon Wren | 7     | Chipping Sparrow<br>Scrub Jay                                                                                                                |
| 3     | Bewick's Wren<br>Downy Woodpecker<br>Common Bushtit<br>Mourning Dove<br>Black-billed Magpie<br>Sharp-shinned Hawk<br>Stellar's Jay<br>Common Flicker<br>Robin              | 8     | Gray-headed Junco<br>Red-breasted Nuthatch                                                                                                   |
| 4     | Band-tailed Pigeon<br>Common Grosbeak<br>Orange-crowned Warbler<br>Swainson's Thrush<br>Yellow Warbler<br>Yellow-bellied Sapsucker<br>Wilson's Warbler                     | 9     | Ruby-crowned Kinglet<br>Vesper Sparrow<br>Mountain Bluebird                                                                                  |
| 5     | Black-chinned Hummingbird<br>Green-tailed Towhee<br>Solitary Vireo                                                                                                         | 10    | Black-capped Chickadee<br>Cassin's Kingbird<br>Red Crossbill<br>Lesser Goldfinch                                                             |
|       |                                                                                                                                                                            | 11    | Brown Creeper                                                                                                                                |
|       |                                                                                                                                                                            | 12    | Cassin's Finch<br>Golden-crowned Kinglet                                                                                                     |
|       |                                                                                                                                                                            | 13    | Gray Flycatcher<br>Western Bluebird<br>Audubon's Warbler                                                                                     |





R=RIPARIAN  
 PJS=PINYON-JUNIPER-SAGE  
 PJM=PINYON-JUNIPER-MIXED SHRUB

Fig. 9. Dendrogram of cluster analysis of 66 bird species by niche overlap habitat and seasonal data. For identification of bird species found in each group see Table 6.

\_\_\_\_\_. 1977. Estimating breeding season bird densities from transect counts. *Auk* 94:455-468.

GREGORY, H. E. 1916. The Navajo country: a geographic and hydrographic reconnaissance of parts of Arizona, New Mexico, and Utah. United States Geological Survey Watersupply paper. Washington, D.C.

\_\_\_\_\_. 1917. Geology of the Navajo country: a reconnaissance of parts of Arizona, New Mexico, and Utah. United States Geological Survey Professional Paper 93. Washington, D.C.

HACK, J. T. 1942. The changing physical environment of the Hopi Indians of Arizona. Papers of the Peabody Museum of American Archaeology and Ethnology, Harvard University, Vol. 35, No. 1. Reports of the Awatovi Expedition, No. 1. Cambridge.

\_\_\_\_\_. 1945. Recent geology of the Tsegi Canyon. Appendix I in R. L. Beals, George W. Brainerd, and Watson Smith, eds. Archaeological studies in northeast Arizona. Univ. of California Press, Berkeley and Los Angeles.

HARSHBARGER, J. W., C. A. REPENNING, AND J. H. IRWIN. 1957. The stratigraphy and the uppermost Triassic and Jurassic rocks of the Navajo country. United States Geological Survey Professional Paper 291. Washington, D.C.

JOHNSGARD, P. A., AND W. H. RICKARD. 1957. The relation of spring bird distribution to a vegetation mosaic in southeastern Washington. *Ecology* 38:171-174.

JOHNSON, N. K. 1975. Controls of numbers of bird species in montane islands in the Great Basin. *Evolution* 29:545-567.

JOHNSTON, D. W., AND E. P. ODUM. 1956. Breeding bird population in relation to plant succession on the Piedmont of Georgia. *Ecology* 37:50-62.

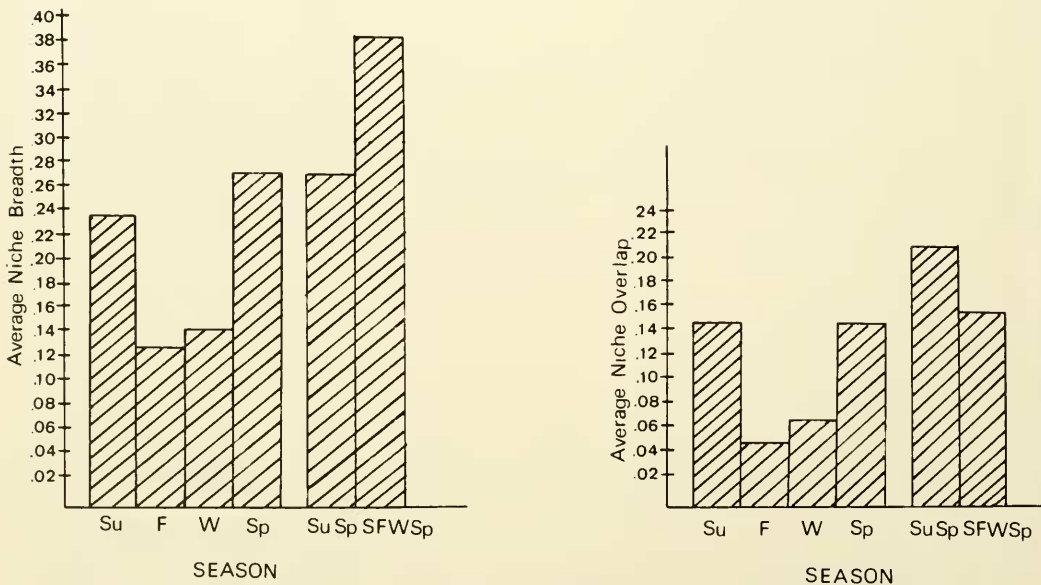


Fig. 10. Histograms comparing average niche breadths and average niche overlaps of bird species by season.

- KARR, J. R. 1968. Habitat and avian diversity in strip-mined land in east central Illinois. *Condor* 70:348-357.
- . 1976. Seasonality, resource availability, and community diversity in tropical bird communities. *Amer. Natur.* 110:973-994.
- KARR, J. R., AND R. R. ROTH. 1971. Vegetation structure and avian diversity in several New World areas. *Amer. Natur.* 105:423-435.
- KIRCHER, J. C. 1972. Birds species diversity: the effect of species richness and equitability on the diversity index. *Ecology* 53:278-282.
- LLOYD, M., AND R. J. GHELARDI. 1964. A table for calculating the "equitability" component of species diversity. *J. Anim. Ecol.* 33:217-225.
- MACARTHUR, R. H., AND J. W. MACARTHUR. 1961. On bird species diversity. *Ecology* 42:594-598.
- MAY, R. M. 1975. Patterns of species abundance and diversity. In M. L. Cody and J. M. Diamond, eds. *Ecology and evolution of communities*. Belknap Press of Harvard Univ. Press, Massachusetts. 543 pp.
- PIELOU, E. C. 1975. *Ecological diversity*. John Wiley and Sons. New York. 165 pp.
- ROSENZWEIG, M. L. 1975. On continental steady states of species diversity. In M. L. Cody and J. M. Diamond, eds. *Ecology and evolution of communities*. Belknap Press of Harvard Univ. Press, Massachusetts. 543 pp.
- ROTH, R. R. 1977. The composition of four bird communities in south Texas brush grasslands. *Condor* 79:417-425.
- RUZICKA, M. 1958. Anwendung Mathematisch-Statistischer Method in der Gebotanik (Synthetische bearbeitung von aufnahmen). *Biologia, Bratisl.* 13:647-661.
- SNEATH, R. H. A., AND R. F. SOKAL. 1973. *Numerical taxonomy: principles and practices of numerical classification*. W. H. Freeman Co., San Francisco. 573 pp.
- TOMOFF, C. S. 1974. Avian species diversity in desert shrub. *Ecology* 55:396-403.
- WILLSON, M. F. 1974. Avian community organization and habitat structure. *Ecology* 55:1017-1029.
- WHITMORE, R. C. 1975. Habitat ordination of the passerine birds of the Virgin River Valley, southwestern Utah. *Wilson Bull.* 87:65-74.
- . 1977. Habitat partitioning in a community of passerine birds. *Wilson Bull.* 89:253-265.
- WOODBURY, A. M. 1963. Biological-ecological aspects of Betatakin Canyon, Navajo National Monument, Arizona. Institute of Environmental Biological Research, Univ. of Utah. Division of Biological Sciences Miscellaneous Papers No. 2. 56 pp.
- YEATON, R. I. 1974. An ecological analysis of chaparral and pine forest bird communities on Santa Cruz island and mainland California. *Ecology* 55:959-977.

APPENDIX

Navajo National Monument  
Field Bird Checklist\*

STATUS

- S = Spring  
Su = Summer  
F = Fall  
W = Winter  
H = General habitat preferences

HABITAT TYPE

- PJ = Pinyon-Juniper and sagebrush  
SI = Slickrock and canyon escarpment creek bottom  
R = Riparian (aspen-oaks along creek bottom)  
G = General distribution throughout the park

ABUNDANCE

- c = common; easily found in proper habitat in the right season.  
f = fairly; may be found in low numbers scattered through the proper habitat in the right season.

- u = uncommon; present but not easily found.  
o = occasional; unpredictable occurrence, seen only a few times during a season.  
r = rare; seen at intervals of two to five years.

| SPECIES            | STATUS AND ABUNDANCE |    |   |   |   |
|--------------------|----------------------|----|---|---|---|
|                    | S                    | Su | F | W | H |
| Turkey Vulture     | c                    | c  |   |   | G |
| Cooper's Hawk      | u                    | u  | u |   | R |
| Sharp-shinned Hawk | u                    | u  | u |   | R |
| Red-tailed Hawk    | u                    | u  | u | u | G |
| Swainson's Hawk    | o                    | o  | o |   | G |
| Golden Eagle       | o                    | o  | o | o | G |
| Prairie Falcon     | r                    | r  | o | r | G |
| Merlin             | r                    |    | r |   | R |
| American Kestrel   | f                    | f  | u | o | G |
| Gambel's Quail     | o                    | o  | o | o | R |
| Killdeer           | r                    | r  | r |   | R |
| Solitary sandpiper | r                    |    | r |   | R |
| Spotted Sandpiper  | r                    | r  | r |   | R |

\*This checklist includes the 72 species listed on "Checklist of Birds, Navajo National Monument, Arizona" as well as 63 additional species observed in the present study.

| SPECIES                   | STATUS AND ABUNDANCE |    |   |   |    | SPECIES                 | STATUS AND ABUNDANCE |    |   |   |    |
|---------------------------|----------------------|----|---|---|----|-------------------------|----------------------|----|---|---|----|
|                           | S                    | Su | F | W | H  |                         | S                    | Su | F | W | H  |
| Ring-billed Gull          | r                    |    | r |   | G  | Stellar's Jay           | u                    | u  | f | r | G  |
| Band-tailed Pigeon        | u                    | u  |   |   | R  | Scrub Jay               | c                    | c  | c | f | G  |
| Rock Dove                 | o                    | o  | o | r | S  | Pinyon Jay              | u                    | u  | u | f | PJ |
| Mourning Dove             | c                    | c  | c | o | G  | Black-billed Magpie     | o                    | o  | o | o | G  |
| Yellow-billed Cuckoo      |                      | u  |   |   | G  | Clark's Nutcracker      | r                    | r  | r | r | G  |
| Screech Owl               | u                    | u  | u | u | G  | Common Raven            | c                    | c  | c | c | G  |
| Great Horned Owl          | f                    | f  | f | f | G  | Common Crow             | u                    | o  | u | o | G  |
| Long-eared Owl            | o                    | o  | o | o | G  | Black-capped Chickadee  | o                    | o  | o | o | G  |
| Spotted Owl               | o                    | o  | o | o | G  | Mountain Chickadee      | c                    | c  | c | c | G  |
| Saw-whet Owl              | r                    |    | r | r | G  | Plain Titmouse          | c                    | c  | c | c | PJ |
| Flammulated Owl           | u                    | u  | u |   | G  | Common Bushtit          | c                    | c  | u | o | PJ |
| Pygmy Owl                 | o                    | o  | o | o | G  | White-breasted Nuthatch | f                    | f  | f | f | PJ |
| Poor-will                 |                      | f  |   |   | G  | Red-breasted Nuthatch   | u                    | u  | u | u | G  |
| Common Nighthawk          |                      | f  |   |   | G  | Pygmy Nuthatch          | o                    | o  | o | o | PJ |
| Lesser Nighthawk          |                      | u  |   |   | G  | Brown Creeper           | o                    | r  | u | f | G  |
| White-throated Swift      | f                    | f  | u |   | G  | House Wren              | f                    | f  | u |   | R  |
| Broad-tailed Hummingbird  | c                    | c  | u |   | G  | Bewick's Wren           | f                    | f  | u | r | G  |
| Calliope Hummingbird      | o                    |    | o |   | G  | Canyon Wren             | f                    | f  | u | u | SI |
| Black-chinned Hummingbird | u                    | f  | u |   | G  | Rock Wren               | f                    | f  | u | u | SI |
| Rufous Hummingbird        | r                    |    | r |   | G  | Mockingbird             |                      | o  |   |   | PJ |
| Common Flicker            | c                    | c  | f | r | G  | Sage Thrasher           | o                    |    | o |   | PJ |
| Lewis' Woodpecker         | r                    | o  | r |   | R  | Robin                   | f                    | f  | f |   | R  |
| Yellow-bellied Sapsucker  | u                    |    | u | r | R  | Townsend's Solitaire    | o                    | o  | o | o | G  |
| Williamson's Sapsucker    | o                    | o  | o | r | G  | Hermit Thrust           | c                    | c  | u |   | R  |
| Hairy Woodpecker          | c                    | c  | c | c | G  | Swainson's Thrush       | u                    | u  | u |   | R  |
| Downy Woodpecker          | c                    | c  | c | c | G  | Western Bluebird        | u                    | u  | o |   | PJ |
| Western Kingbird          |                      | f  |   |   | G  | Mountain Bluebird       | u                    | u  | u | r | PJ |
| Cassin's Kingbird         |                      | f  |   |   | G  | Blue-gray Gnatcatcher   | f                    | c  | u |   | G  |
| Ash-throated Flycatcher   | c                    | c  | f |   | G  | Golden-crowned Kinglet  | o                    |    | o | u | PJ |
| Black Phoebe              |                      | o  |   |   | R  | Ruby-crowned Kinglet    | f                    | o  | f |   | G  |
| Say's Phoebe              |                      | o  |   |   | R  | Bohemian Waxwing        |                      |    |   | r | PJ |
| Willow Flycatcher         | f                    | f  | u |   | G  | Cedar Waxwing           | o                    |    | o | o | PJ |
| Hammond's Flycatcher      | u                    | u  | u |   | PJ | Northern Shrike         |                      |    |   | r | G  |
| Dusky Flycatcher          | u                    | f  | u |   | PJ | Loggerhead Shrike       | u                    | u  | u | o | G  |
| Western Flycatcher        | u                    | f  | u |   | R  | Starling                | o                    | o  | o | o | Ca |
| Olive-sided Flycatcher    | u                    | u  | u |   | R  | Barn Swallow            |                      | o  |   |   | SI |
| Barn Swallow              |                      | o  |   |   | SI | Cliff Swallow           |                      | o  |   |   | SI |
| Cliff Swallow             |                      | o  |   |   | SI | Violet-green Swallow    | c                    | c  | c |   | G  |
| Violet-green Swallow      | c                    | c  | c |   | G  | Solitary Vireo          | c                    | c  | u |   | R  |
|                           |                      |    |   |   |    | Warbling Vireo          | u                    | f  |   |   | R  |

| SPECIES                     | STATUS AND ABUNDANCE |    |   |   |    | SPECIES                | STATUS AND ABUNDANCE |    |   |   |    |
|-----------------------------|----------------------|----|---|---|----|------------------------|----------------------|----|---|---|----|
|                             | S                    | Su | F | W | H  |                        | S                    | Su | F | W | H  |
| Orange-crowned Warbler      | u                    | r  | u |   | R  | Purple Finch           |                      |    | r |   | R  |
| Virginia's Warbler          | f                    | c  | u |   | R  | Cassin's Finch         | u                    | o  | u | f | G  |
| Yellow Warbler              | f                    | c  | u |   | R  | House Finch            | f                    | f  | f | f | G  |
| Yellow-rumped Warbler       | c                    | f  | c |   | G  | Pine Grosbeak          |                      |    |   | r |    |
| Black-throated Gray Warbler | f                    | c  | u |   | PJ | Pine Siskin            | u                    |    | u | u | G  |
| Yellowthroat                | f                    | f  | u |   | R  | American Goldfinch     | u                    | o  | u | u | G  |
| Yellow-breasted Chat        | u                    | f  | o |   | R  | Lesser Goldfinch       | u                    | f  | u |   | SI |
| MacGillivray's Warbler      | f                    | f  | f |   | R  | Red Crossbill          | r                    | r  | r | r | PJ |
| Wilson's Warbler            | f                    |    | f |   | R  | Green-tailed Towhee    | f                    | f  | f |   | R  |
|                             |                      |    |   |   |    | Rufous-sided Towhee    | c                    | c  | c | o | R  |
| House Sparrow               | u                    | u  | u | u | G  | Brown Towhee           | o                    | o  |   |   | G  |
|                             |                      |    |   |   |    | Savannah Sparrow       | o                    | o  | o |   | R  |
| Western Meadowlark          | u                    | u  | u | u | G  | Vesper Sparrow         | o                    | o  | o |   | G  |
| Red-winged Blackbird        | u                    | u  | u |   | G  | Lark Sparrow           | u                    | u  | u |   | PJ |
| Brewer's Blackbird          | u                    | u  | u |   | G  | Black-throated Sparrow | o                    | o  | o |   | PJ |
| Brownheaded Cowbird         | f                    | f  | u |   | G  | Sage Sparrow           | o                    | o  | o |   | PJ |
| Bullock's Oriole            | u                    | f  | u |   | R  | Dark-eyed Junco        | f                    | f  | c | c | G  |
|                             |                      |    |   |   |    | Gray-headed Junco      | u                    | u  | u | u | PJ |
| Western Tanager             | u                    | f  | u |   | G  | Chipping Sparrow       | c                    | c  | c | o | PJ |
|                             |                      |    |   |   |    | Brewer's Sparrow       | o                    | u  | o |   | PJ |
| Black-headed Grosbeak       | u                    | f  | u |   | R  | White-crowned Sparrow  | f                    |    | f | u | G  |
| Evening Grosbeak            | o                    | o  | o | u | G  | Fox Sparrow            | u                    |    | u | o | G  |
| Blue Grosbeak               |                      | r  |   |   | R  | Lincoln's Sparrow      | o                    | u  | o |   | R  |
| Lazuli Bunting              | o                    | o  | o |   | R  | Song Sparrow           | o                    |    | o | o | R  |